

**Consortium for
Electric
Reliability
Technology
Solutions**

**Area Control Error
(ACE) and Frequency
Real Time Monitoring
System**

**Department of Energy Prime
Contract No. DE-AC03-76SF00098**

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Completion Summary Report Of Program Software

Prepared by:

 **Electric Power Group**

for

CERTS
CONSORTIUM FOR ELECTRIC RELIABILITY TECHNOLOGY SOLUTIONS



Area Control Error and Frequency (ACE-Frequency) Real-Time Monitoring System

The Consortium for Electric Reliability Technology Solutions (CERTS) has been working with the North American Electric Reliability Council (NERC) on research and development of tools and technologies for management of grid reliability. This report presents the summary of the completed work effort and describes the applications and functions of the software. The ACE-Frequency Real-Time Monitoring System[®] was developed by the Electric Power Group (EPG) under the direction of CERTS. The CERTS development team was led by Carlos Martinez of the Electric Power Group. The ACE-Frequency Real-Time Monitoring System is one of the applications developed by EPG as part of Grid Real-Time Performance Monitoring and Prediction Platform (Grid-3P[®]) to provide the capability to monitor grid reliability and market performance in real time. The Grid-3P[®] can be used by NERC for ACE-Frequency Real-Time Monitoring System[®] and other applications to monitor grid reliability.

This CERTS project was funded by the Department of Energy, Office of Power Technologies, Transmission Research Program, Phil Overholt, Program Manager. CERTS research program is managed by Lawrence Berkeley National Lab, Joe Eto, Program Manager.

1. INTRODUCTION

The North American Electric Reliability Council (NERC) is in the process of developing mandatory compliance standards. An important aspect of a standard is the associated performance metrics that are employed to determine if the appropriate entities are in compliance. The Consortium for Electric Reliability Technology Solutions (CERTS) has been working with NERC and other organizations to research, develop, and disseminate new methods, tools and technologies to protect and enhance the reliability of the U.S. electric power system under the emerging competitive electricity market structures. The monitoring system also offers a base from which grid security can be improved to help protect the market from “gaming”, and market manipulations. In particular, CERTS has developed and demonstrated the Grid Real-Time Performance Monitoring and Prediction Platform (Grid-3P[®]) for developing applications to manage grid reliability and monitor market performance in real time. Grid 3P complements and integrates with existing SCADA systems and utilizes real time data engines and graphic-geographic visualization tools to develop reliability applications to assist operating authorities, e.g., Independent System Operators (ISO's), Regional Transmission Organizations (RTO's), Reliability Coordinators and Control Area Dispatchers in their management of grid reliability.

The ACE-Frequency Monitoring System using CERTS' Grid-3P, will enable NERC Reliability Coordinators to monitor ACE-Frequency performance and compliance with performance operational guides within their jurisdictions, and will also allow NERC Staff and Subcommittees to analyze and assess control data to improve reliability performance. The ACE-Frequency Real-Time Monitoring System translates raw operational control data into meaningful operations performance information for end users. Should an abnormal interconnection frequency occur, a Real-Time Interconnection Abnormal Frequency Notification (AFN) is automatically issued via email or beepers describing the date, time, and magnitude of the frequency abnormality to specific Operational Authorities, NERC Resources Subcommittee members, and NERC Staff. The notification recipients using the ACE-Frequency Monitoring System functionality can quickly assess the abnormality's root cause by drilling down from wide-area to local-area visualization displays that include appropriate information and analysis graphs to easily identify and assess those control area(s) out of compliance and potential originators of the notified interconnection frequency abnormality.

The key elements of the ACE-Frequency Monitoring System include the following:

- Enables monitoring of ACE for each of the 123 Control Areas operating in the U.S. The data is updated every one to four minutes.
- The Grid-3P visualization infrastructure provides color coded graphics displays indicating status of a region...control area, reliability authority or interconnection.
- Monitoring functions that provide details of various functions allowing users to drill down to the desired level of data and graphic displays for key diagnostics.
- The Real Time Interconnection Abnormal Frequency Notification (AFN) issues email notifications and enables the user to assess the root-cause for abnormal frequencies.
- ACE-Frequency Data Collection Tool archives raw data from the NERC Database for review and analysis.

2. ACE-FREQ REAL-TIME MONITORING SYSTEM OVERVIEW

2.1. Development of the Grid Performance Monitoring and Prediction Platform (GRID-3P)

The vertically integrated business model historically used by utilities has evolved to a segmented market dispersed among separate entities. The top part of Figure 1 shows the current business model being segmented into generation, transmission, distribution, markets and security. The Grid Real-Time Performance Monitoring and Prediction Platform (Grid-3P) has been developed by CERTS to serve as the base for the development of reliability applications for real-time monitoring and prediction for the reliability performance of control areas, generation, grid, markets, and security. Control area's ACE, interconnection's frequency and interchange data on top of the Grid-3P provide a common tool to be utilized by NERC Reliability Coordinators, Control Area Dispatchers, and Transmission Dispatchers. The bottom of Figure 1 also shows that reliability applications developed using Grid-3P serve as complement for traditional SCADA/EMS systems and for the periodic reporting requested by NERC for post performance assessment.

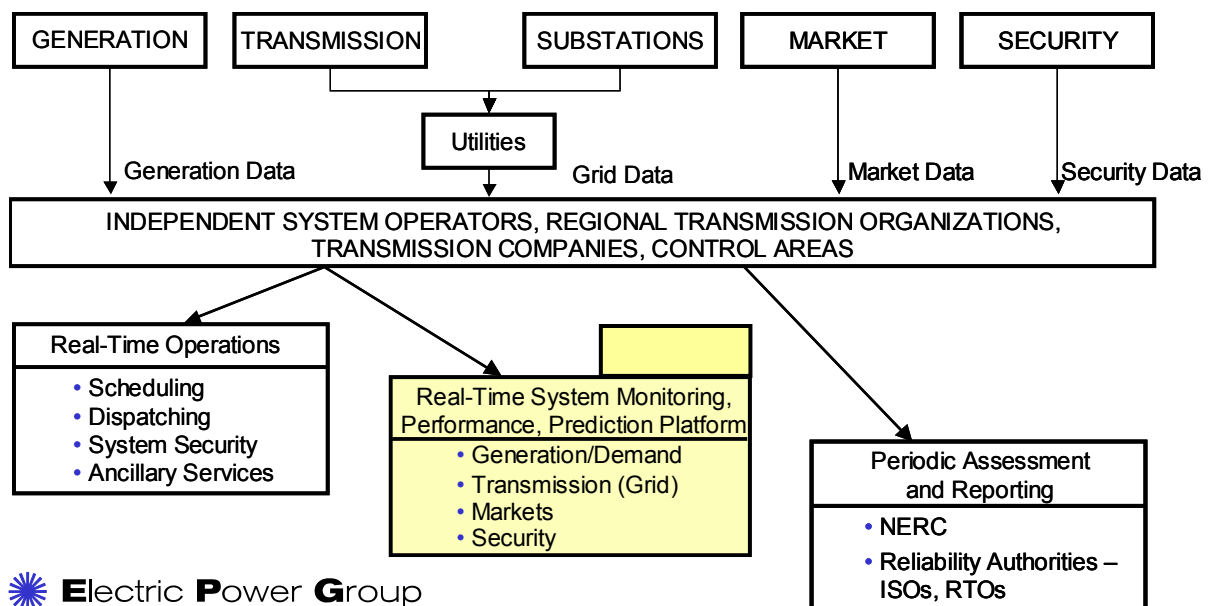


Figure 1 – Grid-3P for Real-Time Grid Monitoring

Figure 2 below shows an expansion of the Grid-3P block from Figure 1 and includes the major reliability applications for real-time reliability monitoring for NERC Reliability Coordinators and Control Area Dispatchers. The top part from Figure 2 shows the applications target for Reliability Coordinators, ACE-Frequency, AIE and Control Performance Standards (CPS). The bottom part from Figure 2 shows the applications target to Control Area Dispatchers, performance compliance of control areas, suppliers to AGC, FRR and Ancillary Services markets. NERC Reliability Coordinators monitor several requirements, including ACE-Frequency, to maintain and enhance the reliability of their jurisdictions. The ACE-Frequency Monitoring System, shown in the upper applications box, provides applications for each Coordinator within each of their reliability regions. Reliability Coordinators utilize those applications to monitor performance and compliance within their regions and notify the appropriate Control Area Dispatchers as abnormalities occur. Control Area Dispatchers pinpoint problem sources by monitoring the response performance of their control areas and suppliers to the Automatic Generation Control (AGC) Monitoring System, Frequency Response Resources, and Ancillary Services.

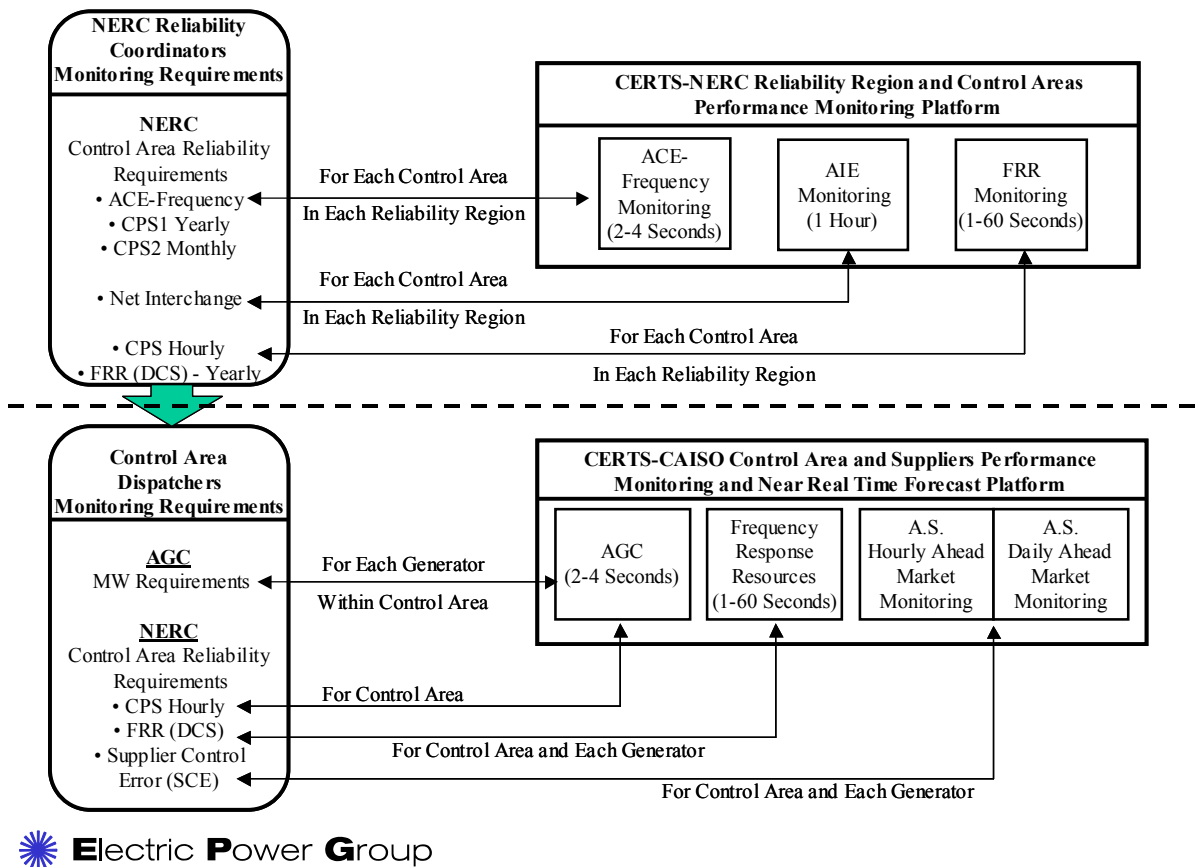


Figure 2 – Grid-3P Applications for Reliability Coordinators and Control Area Dispatchers

CERTS is developing the Reliability Coordinator applications for NERC, and the Control Area applications for the California Independent System Operators (CAISO). Close coordination has been maintained to ensure compatibility with NERC needs.

Figure 3 illustrates the architecture of the ACE-Frequency Real-Time Monitoring application using CERTS' Grid-3P. ACE-Frequency receives ACE and frequency data from the nation's Control Areas (Data Collection), calculates performance parameters for each reliability jurisdiction and compares those performance parameters to NERC reliability compliance guides. The results of these comparisons are then displayed graphically (Visualization) on a geographical map (Geography) for use by each of the Reliability Organizations from each of the layers, depicted in the lower, right pyramid. The tiers of the pyramid comprise the Control Areas, Reliability Coordinators, Reliability Transmission Organizations, Reliability Regions, and Interconnections.

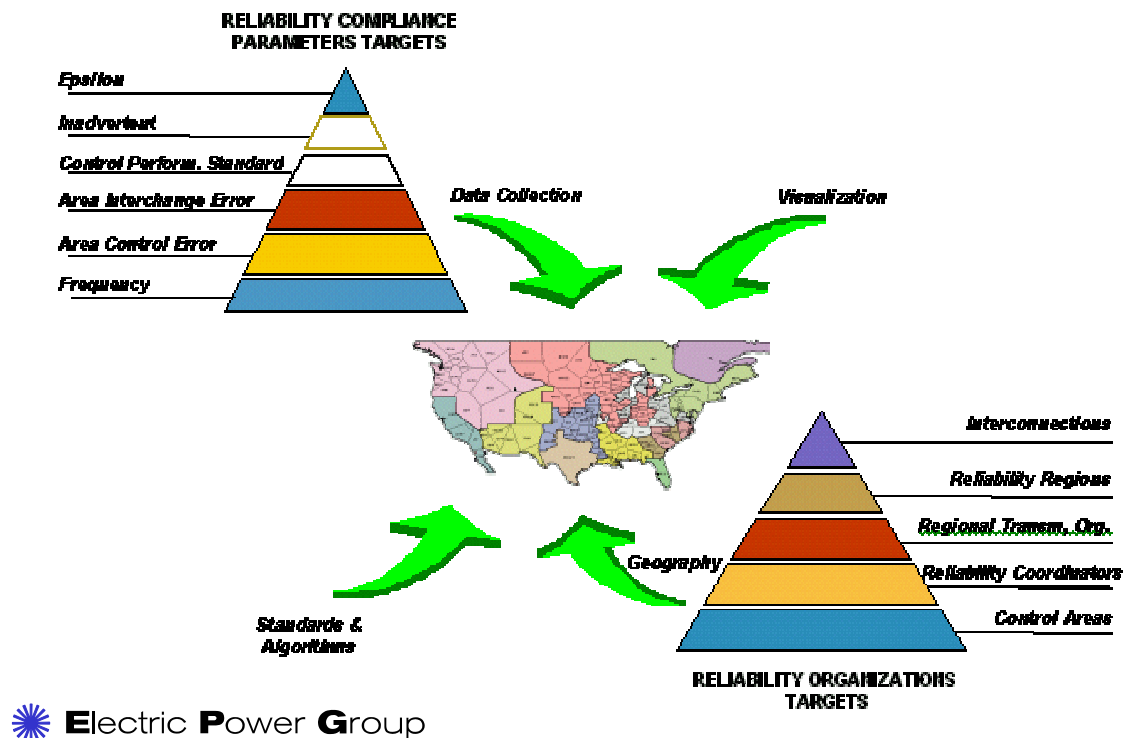


Figure 3 – Schematic Illustration Of The Application of Grid-3P for NERC ACE-Frequency

2.2. ACE-Frequency Real-Time Monitoring Functions

Figure 4 below shows the five major functional components of the NERC ACE-Frequency Real-Time Monitoring System: Local Monitoring, Global Monitoring, Abnormal Frequency Notification, Interactive data Collection and Unavailable Data Reporting. Following are description of each one of the components:

Local Monitoring Geographic-Graphic Visualization

Most of the ACE-Frequency visualization is geographic-graphic oriented and covers different time windows from current time to 30-days. The local-visualization option covers from current time to 1-hour, and it offers to end users three different views of Control Area ACE and Interconnection frequency data displayable in the Grid-3P three-panel window visualization.

Global Monitoring Geographic-Graphic Visualization

This option uses the Epsilon performance parameter as an indicator of the frequency performance for each of the interconnections. It shows the performance parameter for two time windows, 6-hours and 30-days. It also uses the Grid-3P three-panel window visualization.

Abnormal Frequency Notification (AFN)

The Real Time Abnormal Frequency Notification (AFN) is a real-time monitoring component of the ACE-Frequency Monitoring System. The AFN is designed for real-time monitoring of abnormal interconnection frequencies, and to automatically issue emails to specific NERC Resources subcommittee members and NERC Staff when predefined

abnormal frequency performance criteria are met. Email recipients can use the ACE-Frequency Monitoring System capabilities to assess root causes of the abnormal frequencies when notified.

The input data to the AFN is provided by Control Areas to NERC over a secure connection using NERCnet, XML, and SOAP technologies.

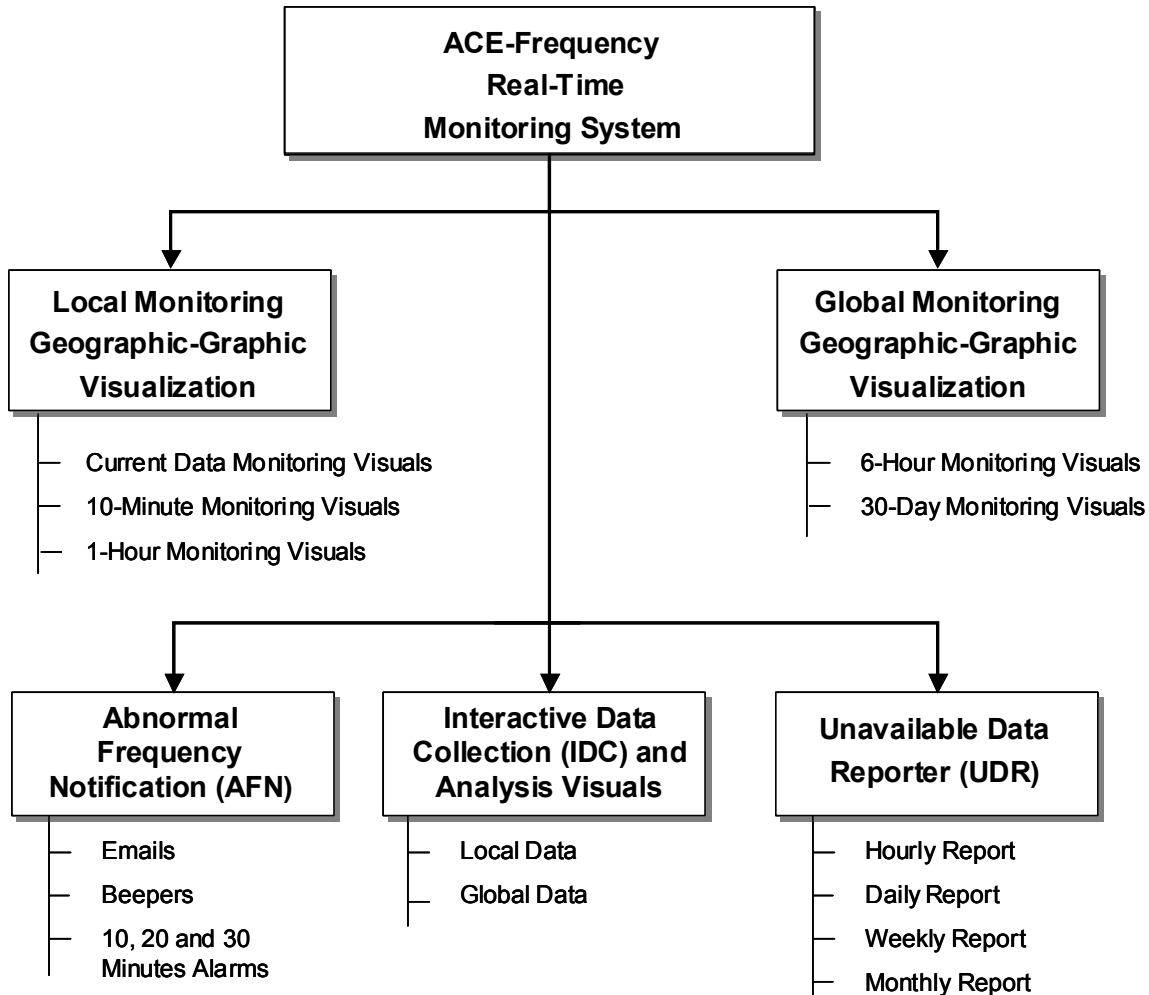


Figure 4 – ACE-Frequency Real-Time Monitoring System Functional Overview

Interactive Data Collection (IDC) Function

Via the IDC functionality, NERC Subcommittees, NERC Staff, and Operating Engineers can interactively define the historical window of time and the specific control-performance parameter they need to analyze and assess frequent disturbances. Once data is collected from the NERC data server, the users can use equivalent reliability coordinator visualization and/or save the data in comma-delimited files.

Unavailable Data Report Generator (DRG) Function

DRG offers the capability to interactively identify and report Control Area data transfer performance. Users can select hourly, daily, weekly, and monthly reports and select the specific data they want to assess for availability.

2.3. ACE-Frequency Real-Time Monitoring Visualization Hierarchy

The more effective operational displays are those that follow a hierarchical approach to present operational data for current time and other key windows of time. Accordingly, the Grid-3P visualization model encompasses displays at high and low levels to meet the varying needs of different reliability application users. Thus, monitoring applications are developed for wide-area and local area users. The hierarchal structure in Figure 5 shows that Reliability Coordinators need to have a wide-area view of their jurisdictions for reliability compliance monitoring. ISO's and RTO's need the ability to assess performance and trends of their control areas. In turn, Control Areas need local area information to pinpoint specific supplier's reliability performance issues. The ACE-Frequency tool allows Reliability Coordinators to monitor ACE-Frequency performance and compliance for each of their jurisdictions using wide-control-area graphic-geographic visualization.

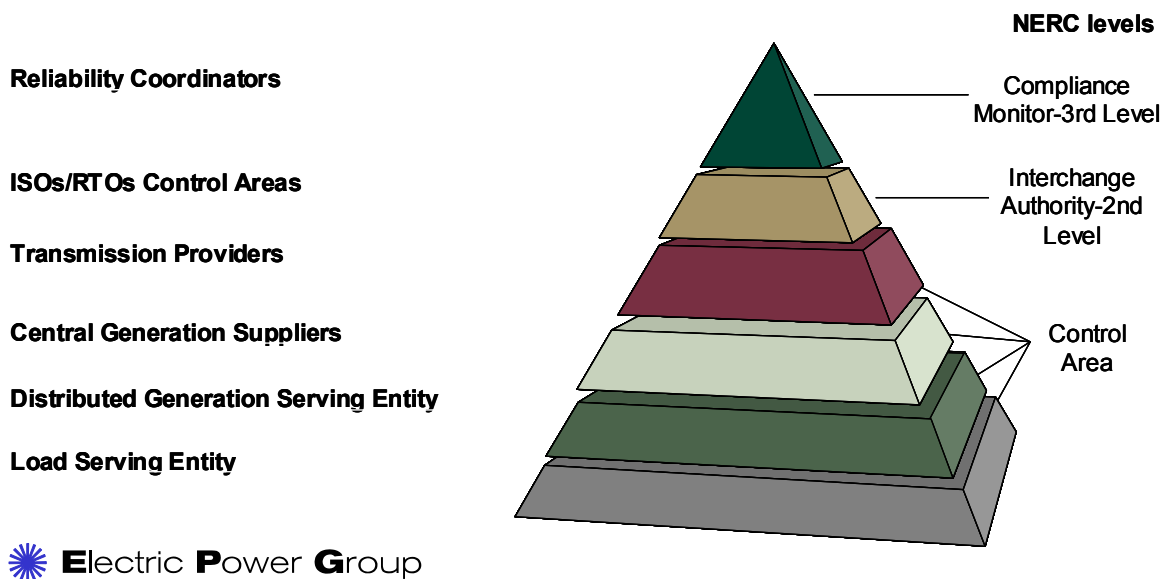


Figure 5 – Reliability Functional Levels and Visualization Hierarchy

For the definition and design of the ACE-Frequency graphic-geographic visuals for each of the visualization layers shown in Figure 5, the Grid-3P data, computational, and visualization models are shown in the first three vertical segments on Figure 6.

2.4. GRID 3-P Visualization Model

For the NERC ACE-Frequency Real-Time Monitoring System, approximately 123 Control Areas transmit ACE and frequency data to a data server located at NERC (data collection). The data is then processed and performance parameters are calculated in the Grid-3P computational engines (computational model); the design and deployment of each of the displays follows the

three steps show in the display model section on Figure 6, Functional; User Interaction and Major Applications.

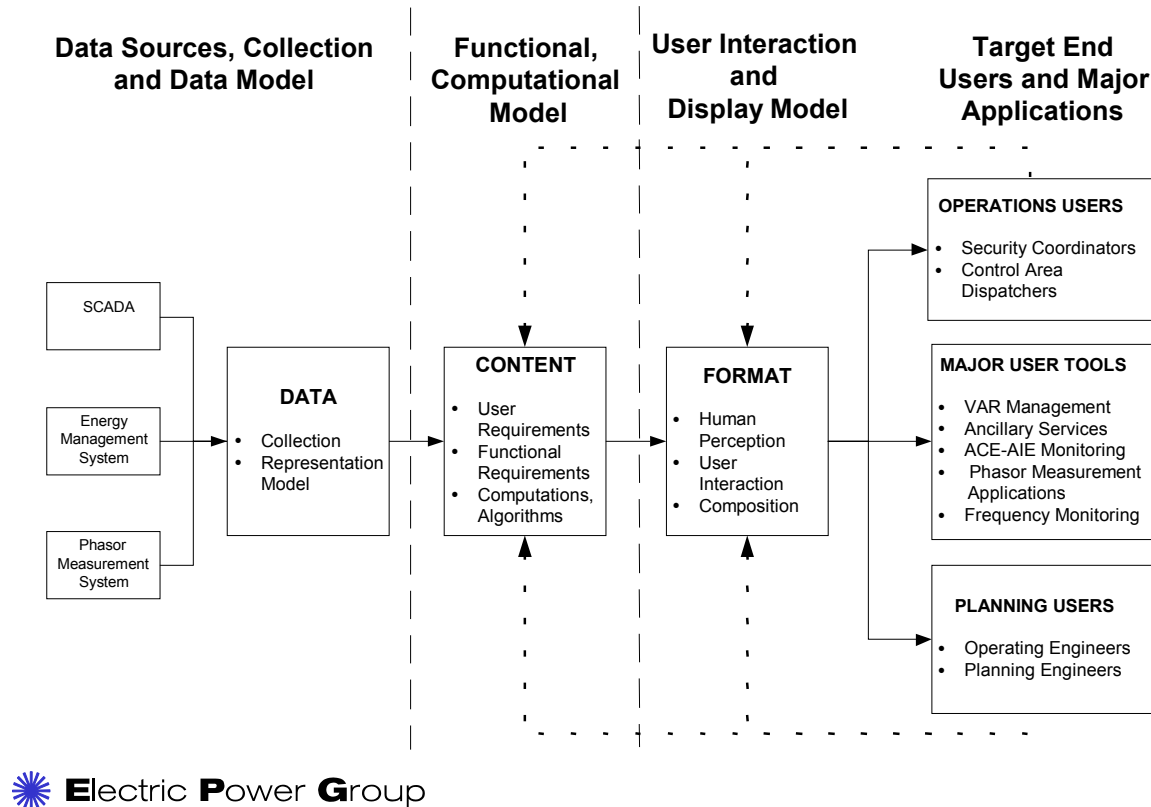


Figure 6 – CERTS Grid-3P Integrated Visualization Model

3.0. ACE-FREQUENCY FUNCTIONALITY – REPRESENTATIVE ILLUSTRATIVE DISPLAYS

The User's Guide "NERC Real Time ACE Monitoring System" identifies 82 figures and graphs that fully illustrate both the capabilities and functions of the software program. A sampling of the geographic visual graphics include:

- Control Area Map showing current status of grid;
- Visualization showing 10 worst Control Areas; and,
 - "Drill Down" tables showing specific Control Area data and information;
- Control Area Map with three panel display (showing last minute ACE and ACE/L₁₀ values)

3.1. Control Area Map

The standard Control Area Map is shown in Figure 7 below. The ACE status of all Control Areas are illustrated by color.

- Red -200 to -100 hertz

- Yellow -100 to 0 hertz
- Green 0 to 100 hertz
- Blue 100 to 200 hertz

The Control Area Map allows for an operator to quickly ascertain grid frequency status by visual observation. Should the operator require additional information on a particular Control Area, grill down tables are available (see below).

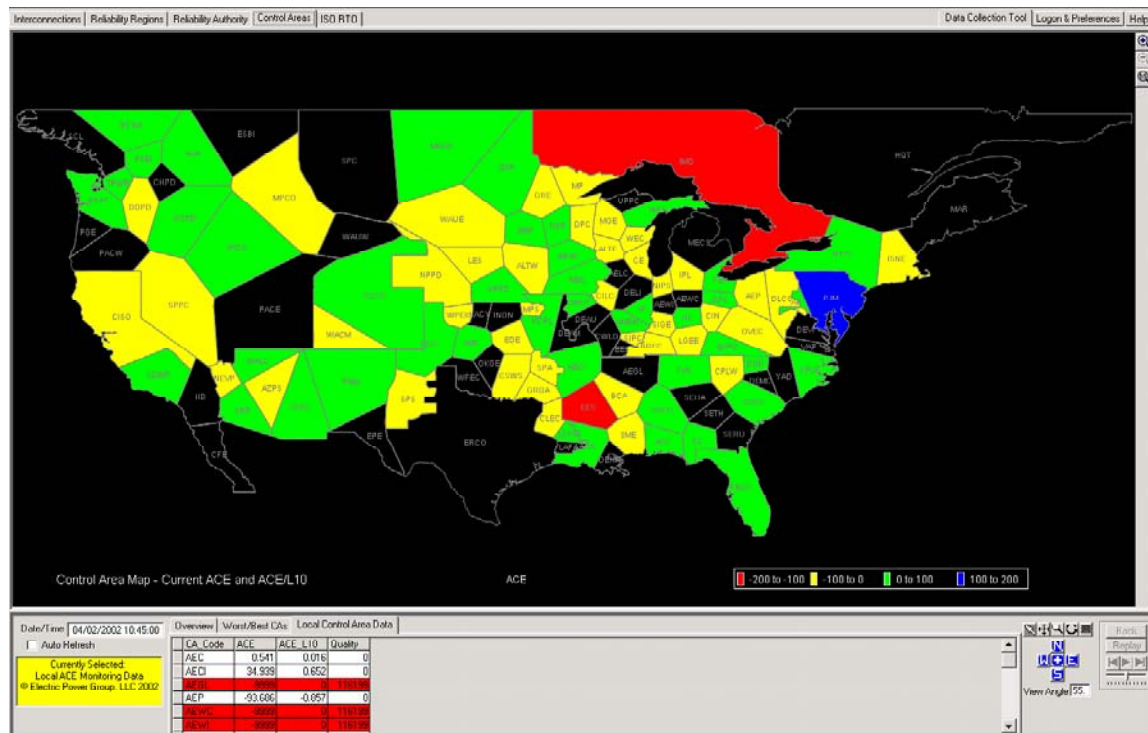


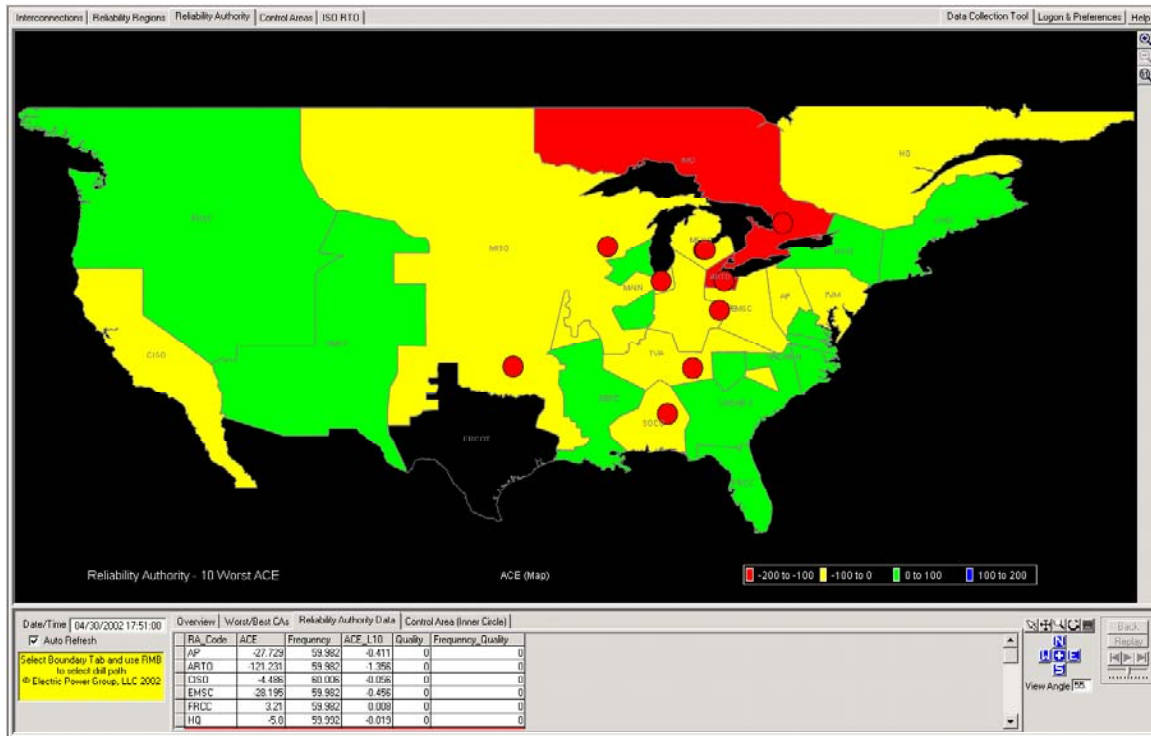
Figure 7 – Control Area Map for ACE

3.2. Ten Worst Area Control Areas and Drill Down Table

Figure 8 below illustrates an example of the geographic visualization graphics capability that identifies the ten worst control areas of the Reliability Regions. This view allows the user to identify, monitor and record the real time ACE-Frequency metrics of the current 10 worst control areas. Once poor performing control areas are identified, a “drill down” on one specific control area can be made with full description of the region, area and detailed breakdown of operating parameters. These parameters are presented in the Table of Figure 9 below and consist of the following data and information:

1. ITC_Code – An abbreviation for Interconnection
2. RTO_Code – Regional Transmission Organization
3. RR_Code – Reliability Region
4. RA_Code – Reliability Area
5. CA_Code – Control Area
6. ACE – Area Control Error
7. Frequency – Frequency reported for the Reliability Authority Area.

8. ACE_L10 - ACE for the CA compared to the L10
9. Quality – Number of minutes data has not been received from a CA
10. Longitude – Plotting coordinate
11. Latitude - Plotting coordinate
12. L10_Yearly – Compares actual ACE for the past 12 months to L10 submitted by the CA



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Figure 8 – Visualization Showing Ten Worst Control Areas

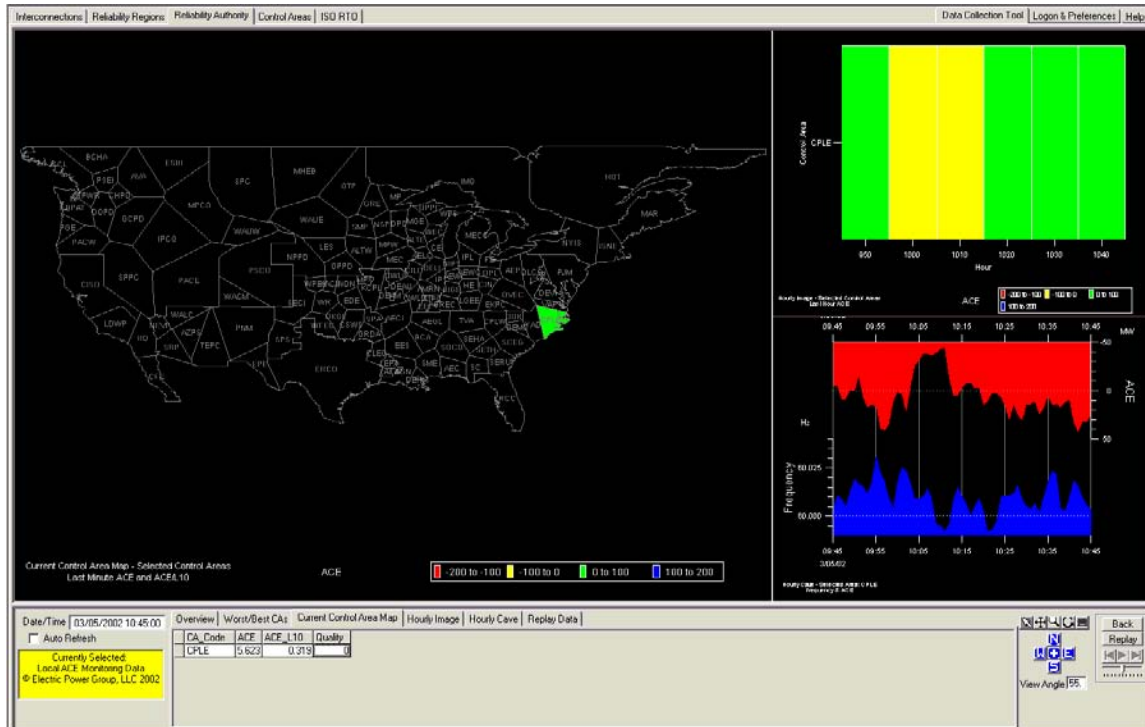
Overview Worst/Best CAs Reliability Authority Data Control Area (Inner Circle)									
ITC_Code	RTO_Code	RR_Code	RA_Code	CA_Code	ACE	Frequency	ACE_L10	Quality	L10
E	MISO_SPP	SPP	MISO	OKGE	0	60.02049999999999	0	1	-97.90000000
E	MISO_SPP	SPP	MISO	SECI	8.474800000000001	60.02049999999999	0.56236230922362307	0	
E	MISO_SPP	SPP	MISO	SPA	2.5146000000000002	60.02049999999999	6.4229885057471264E-2	0	-94.10000000
E	MISO_SPP	SPP	MISO	SPS	10.807600000000001	60.02049999999999	0.21384250098931543	0	-102.60000000

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Figure 9 – “Drill Down” Table

3.3. Control Area Map with Three Panel Display

Figure 10 below illustrates a three panel display for the Carolina Power and Light – East (CPLE) control area. The large map panel shows the location relative to other control areas and the general status of the ACE by color of the CPLE control area. The smaller panel on the top right shows the past 60 minutes status of the ACE also by color. The bottom right panel illustrates the cave graph and displays the specific values of both the corresponding frequency and ACE for the last hour.



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Figure 10 – Control Map of Selected Control Area

4.0. APPLICATION OF THE ACE-FREQUENCY REAL-TIME MONITORING SYSTEM FOR RELIABILITY MANAGEMENT

The ACE-Frequency software program provides the operators with an overall perspective to manage grid reliability; this perspective can be shown nationally and then “grilled down” to provide real time assessment of specific regional and area grid status. In the past, communication between and among control areas was poor and the “fix” for one control area may actually exacerbate problems of another. This program application allows for enhanced communication among the control areas, Reliability Regions and NERC. As part of reliability management, market monitoring can also be accomplished through the comparison of performance of multiple control areas. In addition, through market monitoring, grid security can also be enhanced by ensuring that abnormal market conditions are based on grid and market events and not market “gaming” or artificial influences.

The two primary parameters monitored for reliability management are:

- Area Control Error (ACE); and,
- Frequency.

4.1. ACE Monitoring for Reliability Management

Each of the approximately 123 control areas can be accessed and the ACE or ACE/Frequency values can be displayed. Referring back to Figure 10 above, the control area map shows all of the regional control areas and each area can be accessed to ascertain the ACE and/or ACE/Frequency values. The “grill down” capability of the multi panel visualization and the complimentary data tables allow for a complete and comparative assessment of the overall grid status. By incorporating all regional area data into one overall map, the overall condition of the grid can be determined, assessed and managed to enhanced grid reliability since each individual control area contribution to adjacent grids and to the overall grid will be known.

4.2. Frequency Monitoring for Reliability Management

The development of the Automatic Frequency Notification (AFN) contained within the ACE-Frequency monitoring system allows for real time assessment of the grid status and allows the control areas to determine their compliance (or non-compliance) with NERC criteria. To monitor compliance with the NERC frequency criteria as applicable to each region, the program tracks five parameters and measures these parameters with their NERC default values. These measurements are:

Frequency Short Term Duration

For each interconnection, the program checks to see if the frequency in the last 1 to 2 minutes has changed by more than 20 millihertz. If the variance exceeds this value, then notification (email) is sent to the operator and the amount of variance as well as the frequency immediately prior to the variance is made known to the operator.

Frequency Prolonged Deviation

Once an interconnection has had an occurrence of a Short Term Duration, then the program continues to monitor the frequency to ascertain compliance. If, within 10 minutes, the frequency does not return to normalcy, the operator is again notified of the frequency excursion.

Frequency Long Term Deviation

The average frequency deviation over one hour intervals is also tracked and variations to the regional NERC requirements are sent to the system operator via email.

Frequency Quality Data Problem

NERC has identified certain control areas as primary and secondary providers of frequency. These control areas are to send the frequency data every minute. In the event that the frequency is not sent within a 15 minute timeframe, the system operator is notified.

ACE Quality Data Problem

In addition, to checking for frequency, the AFN also checks for the availability of the ACE data from control areas. If the data has not been sent to NERC for a time greater than thirty (30) minutes, then the system operator will be informed.

5.0. CONCLUSIONS

The ACE-Frequency Real-Time Monitoring System has been developed by Electric Power Group (EPG) to permit grid operational assessment by Control Areas, Regional Reliability Authorities and NERC. The Grid Real Time Performance Monitoring and Prediction Platform (Grid 3-P) platform has been developed to provide monitoring of grid metrics and management of grid reliability in real time through the use of unique geographic graphic visuals; “grill down” capabilities provide specific data on trouble spots and allow pinpointing root problem causes. Automatic functions such as the Abnormal Frequency Notification (AFN) provide constant and automatic vigilance to help ensure grid compliance. The Area Control Error (ACE), frequency excursions and related parameters can be easily and quickly accessed to determine the interrelationship among the control areas as well as compliance to specific regional and area NERC guidelines. The software application developed for CERTS allows market performance monitoring which also helps secure the markets from “gaming” and other artificial market irregularities. When this application is used and aggregated with other EPG developed applications, (Voltage/VARS Management System and Area Interchange Error Monitoring System) a more robust system to manage grid reliability, monitor market performance and help ensure grid security is realized.

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